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Research issues related to the use of simulations and simulators: Lessons learned

David Darvill

Human Factors Division
Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West, P.O. Box 2000
North York, Ontario M3M 3B9

Abstract

In this paper, a number of issues relevant to the use of simulations and simulators for military training are presented. Issues in three domains, i.e., engineering, ergonomics and education, are discussed briefly, with examples drawn from projects at DCIEM related to tank crew training. It is suggested that simulators, used as research devices, can provide useful data to address questions in all three of these domains.

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Defence and Civil Institute of Environmental Medicine,
North York, Ontario M3M 3B9

Introduction

Before discussing issues relevant to the use of simulators for research, let me briefly provide a definition of a simulation or simulator. A simulation can be thought of as simply a metaphor for what is being simulated: it is *like* the real process, equipment or situation. In this regard, most research can be thought of as involving simulations; the procedures used in research answer *what if* questions about some actual equipment, situation or process. Furthermore, a simulator is the physical embodiment of a simulation. Almost any research apparatus thus can be considered to be a simulator, but simulators also are used to train personnel; to help them understand a situation or use a process or operate some equipment. In this presentation, I will briefly discuss several issues that I feel are important to consider when using simulations or simulators for research purposes, citing examples from our experience at DCIEM with tank crew training. Though this experience has not dealt specifically with driver training, the examples do relate to important issues in the design and use of simulators for military training.

Three domains

There are a many issues that are common to the use of simulators for training research and for actual training. To be effective, any simulator needs to be designed to meet the *engineering*, *ergonomic* and *educational* demands of the particular task to be simulated, taught or studied. Decisions about *what to model* and *how to model it* are key questions that must be answered prior to any simulator research or development. The *what* determines the scope of the required simulation; this will usually have a significant impact on *how* the simulation is to be applied as well. Following are some examples of these issues, primarily from a researcher's perspective.

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[1] Paper presented at Second Seminar in Transportation Ergonomics:Vehicle Operation and Simulators, at Montreal, Quebec, October 24-25, 1990.

In the **engineering domain**, it is often taken for granted that a simulation requires the highest possible fidelity to the actual process or equipment being simulated. There are sometimes limits to this pursuit of greater fidelity, however, beyond which the present capabilities of the trainee may not require or be able to take advantage of such improvements. For example, the required resolution of a visual display may change for different training levels or tasks. In training tank gunners, the resolution required for initial training of target detection, tracking and fire control system use is much less than that required for the more difficult tasks of target recognition, i.e., friend or foe, and target identification, i.e., whether a target is an X1 tank or an X2 tank. In driver training, a similar problem involves the choice of image resolution for a visual display. Initially, novices may require only the *shapes* of key road signs, but later in their training both the *shape and text* of signs may be more important and an increase in display resolution may be required. In another example, a more complex visual display may be required to teach experienced drivers how to deal with adverse weather conditions such as rain or fog. In certain cases, exceeding the essential fidelity criteria for the level of training may reduce the cost-effectiveness of the simulator. Determining these cases is one possible area of interest to researchers.

An effective training simulator, in any case, requires appropriate user interfaces based on sound **human factors knowledge**. These interfaces are required for the trainees, but also for other participants in the simulation or training scenario as well, e.g., a confederate or an instructor. There has been much research about the possible relations of trainees to training devices. There has been much less about the needs of others, e.g., those of an instructor in relation to either the student or simulator.

Information obtained from a simulator ideally should include details about the progress of a session as well as the more traditional outcome measures describing how well the trainee has performed. Deciding what level of information about the use of a simulator should be made available as feedback, and to whom, is an important issue. The needs of the student, instructor and researcher most probably differ in this regard. The instructor can use more information than the student needs, but researchers want as much information about the simulator use as possible. By designing simulators with access to all possible inputs and outputs, it would be possible to choose the appropriate feedback level for the intended audience. This, however, is seldom the case, for design or cost reasons, so knowing the intended purposes of the simulator is important.

Following is an example of the usefulness of detailed feedback from a simulator. At DCIEM, we uncovered an important procedural error being made by many of our tank gunners during an evaluation of gunnery skills using a prototype gunnery simulator. The output of the simulator was very detailed, with a record made of the timing and sequencing of all actions by the gunner. From this record, we were able to discover that two switches were being depressed in the wrong order. These switches were quite small and located on the gun controller so that the instructor had little chance to see them and the error was quite subtle in its effects. Without the detailed feedback from the simulator, an instructor would have had little chance of discovering the presence of the error. Indeed, the actual equipment had been in service for many years, with no way of knowing how long the error had been in existence.

In another development at DCIEM related to the use of feedback information from a simulator, we have recently created an 'intelligent' Instructor's Aide to help gunnery instructors use the part-task gunnery simulator. This aide compares the details of the trainee's performance on the simulator to a model based on a task analysis of the expected task behaviour. It then highlights any discrepancies for the instructor. This provides additional support to the instructor, who may have been concentrating on one specific training issue and thus missed an error by the trainee in another area.

To be most effective, then, it is essential that a simulator be viewed as a complete system; one that effectively integrates the student, the simulator and any other aspects of the task or environment, including other persons, that might affect the training *or research* usefulness of the device.

Finally, any effective training that is to use simulations or simulators must be based on sound **pedagogical theory and practice** to ensure that the training system has the capability to teach the student what is required. It is not enough simply to provide a high fidelity simulation of some process or device and expect that a trainee will learn what is required by *playing* with it. The trainee may learn the wrong things!

As an example, in the late 1970s, the Defence Advanced Research Projects Agency (DARPA) in the US developed an interesting tank gunnery trainer based on then-new developments in video arcade game technology. Gunner-trainees using the device were rewarded with higher scores for the greater number of targets they hit. A significant problem with this device was that the gunners were not penalized for the number of shots taken to hit targets. When DCIEM obtained one of these simulators, it was obvious that training tank gunners to hit a target without regard for the number of ammunition rounds expended was not desirable, even if the trainer might improve their hand-eye coordination or knowledge of the fire control system. To prevent this type of *error-learning*, the DCIEM simulator was modified to remove the scoring system and to add an instructor's console to remove the control and monitoring of the gunner's training from the machine. In the realm of driver training, an analogous situation might develop if a driver were trained initially using only simulations of open highways and was then expected to be proficient at driving in a crowded city. Consequently, there should be a sound, well thought out training plan to cover the training requirements associated with simulator use.

Two populations

It is also worth noting that training simulators often serve *two populations* and that the needs of one population cannot always be met with a simulator for the other. On one hand, simulators are used for the **initial training** of novices, who may bring only some general skills to the task. It may even be necessary to improve some of these general skills before the teaching of specific new skills can begin. On the other hand, simulations or simulators are also used for **continuation training** of already learned skills or for upgrading experienced operators who must learn about new procedures or modified equipment. Whether or not to use a single simulation for both purposes and whether this will provide the most effective training for all cases are issues for researcher to address.

Evaluation and transfer of training

As either researcher or trainer, we are always keenly interested in the effectiveness of a simulation or simulator. The principle problem most often encountered in either realm, however, is related to the evaluation of the training or a trainer. *Transfer of training* is probably the most important issue in simulator research or development, or for that matter in most other types of training research. Establishing what to measure involves making clear statements about what the simulation was supposed to teach and how it was to teach it. Evaluation can be of the on-going process during use of the simulation or it can be based on some end-product evaluation measure. The latter measures are often provided through use of the operational equipment to obtain some criterion measure of learning transfer. An on-going evaluation may be based on information gathered from the use of the simulation or through testing using the actual equipment during the training period. With the present developments in simulation methods and technology, there is also the possibility that training on one basic simulator can be evaluated on another more comprehensive simulation and so on until the operational equipment must be used. Examples of this in a military context are the use of a driver's station mock-up, then a stripped down chassis, then the actual vehicle to train tank drivers in the skills needed to perform all of the procedures required to do their job. One of many problems that exist in the military setting, and that may exist in other settings as well, is that the trained driver can seldom, if ever, be tested fully in the context of the job that he or she was being trained to do. Missing from most normally available evaluation contexts, whether using a more complex simulator or perhaps a war game exercise, will be some elements of the *real thing* , e.g., certain stresses, anxieties or motivations, that may be important for the given training to be truly effective. Consequently, there will always be some lingering doubt about the actual extent of the transfer of that training.

Environment

Any simulation or simulator needs to be designed, built and evaluated within the overall context of the environment where the task occurs or where the equipment is to be used, to the extent that this can be done. Obviously, one can simulate a greater or lesser portion of the overall task or of the complete equipment. Decisions about the level of simulation can have important consequences for the researcher. Even adequate simulations of many small parts of a larger task will not guarantee that you will have an effective trainer when all of these bits are connected in a more comprehensive simulator.

We use part-task simulations or simulators because there is an interest in partial process learning, in the measurement of specific training effects, or in the transfer of the partial training to other simulators or to the real equipment. The only complete simulator will be the actual equipment being used in the actual manner in the actual environment. All others are, in fact, part-task trainers to a greater or lesser degree. In many military settings it is indeed unlikely that the full operational context for the training will ever be realized, leaving always some measure of doubt about the effectiveness of any trainer.

Conclusion

Without doubt, simulations and simulators are becoming more prevalent for training purposes. Although using the actual equipment is probably the most effective means of training in many circumstances, this is not always possible. Operational constraints or safety considerations may prevent the use of the actual equipment, whether that equipment is a vehicle such as a tank or a sophisticated control panel such as found in a nuclear power plant. Novices make errors while learning and their mistakes could be very costly if made using the equipment *in situ*. Simulations and simulators can help alleviate this worry, but , as has been suggested, they can also introduce other problems. As engineers, ergonomists and educators, we must be aware of these potential problems and, if found, discover ways to solve them.

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